

## ***In Situ* Treatment of Oiled Sediment Shorelines Programme**

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### **ABSTRACT**

The *In Situ* Treatment of Oiled Sediment Shorelines (ITOSS) Programme is an international project with the primary objectives to investigate natural shoreline cleaning processes and the treatment methods by which these processes can be accelerated. The initial emphasis of the investigations is to better understand oil fine-particle interaction (OFI) and mechanical abrasion processes. The first set of studies was carried out in laboratory basins in Trondheim in February, 1997. These studies focused on the removal of oil due to natural abrasion and accelerated abrasion as a function of wave energy and oil loading. This set of studies also served to develop and verify experimental procedures to be used in other studies under this Programme. The second set of studies was carried out in the Coastal Oilspill Simulation System (COSS) basins in Corpus Christi, Texas, in April-May 1997. These studies involved the investigation of natural processes of oil removal in the presence of clays, the effectiveness of abrasion, and the use of *in-situ* shoreline cleanup techniques to accelerate these two processes. The Svalbard field trials to be conducted in August, 1997, will use the results from the first two studies to conduct full-scale tests on low-energy, mixed sediment beaches. All of the three studies described use a single oil batch, an IF 30 fuel oil.

### **INTRODUCTION**

The *In Situ* Treatment of Oiled Sediment Shorelines (ITOSS) Programme has been designed to investigate both the effectiveness of mainstream *in-situ* shoreline cleanup techniques and the natural processes for oil removal from shorelines, in particular through oil and fine particle interaction. Studies carried out within the Programme are part of a larger framework of linked studies being carried out by various agencies in a long-term strategy to better understand the fate and behaviour of oil on shorelines. These results then will be used to develop appropriate response options for oiled shorelines, particularly in remote areas.

### **BACKGROUND**

*In-situ* shoreline techniques may be applied anywhere in the world and on various types of beaches and stranded oils. Such techniques generally require fewer resources, less logistic support, and generate little or no waste materials when compared to physical removal techniques. *In-situ* techniques are particularly attractive for remote or inaccessible areas, such as are common on the coasts of northern Canada, Russia, Scandinavia, and Alaska. In broad scope, ITOSS will investigate the *in-situ* techniques of surf washing (sediment relocation), tilling, bioremediation, and both natural and

enhanced removal by oil and fines interaction (OFI)<sup>1</sup>. These techniques have been used on many occasions to date, but only qualitative data are available regarding relative efficiencies and the relationship between effort and success. Surf washing to accelerate natural weathering on lower wave-energy coasts through fine-particle interaction, as opposed to surf washing to induce mechanical abrasion on higher-energy coasts, is now becoming better understood as laboratory work on OFI progresses. However, to date only post-spill studies have been conducted and the time is considered appropriate to evaluate the technique by basin-scale and field-scale trials.

The concept of an interaction between stranded oil and fine particles has received some attention in recent years. In the natural environment, the process has been investigated in the context of field samples collected from a number of past spills (*Exxon Valdez*, *Arrow*, *Metula*, *Nosac Forest*, Tampa Bay, BIOS). This process may explain why and how oil is removed naturally from surface and subsurface sediments in areas where natural wave energy levels are too low to physically or mechanically abrade residual oil (Bragg and Owens, 1995). The acceleration of this natural process also has been pursued on two spills, Tampa Bay (Owens *et al.* 1995) and the Sea Empress (Lunel *et al.* 1996) and the technique generally has been known as surf washing.

### **The Three Scale Approach in ITOSS**

ITOSS provides for the conduct of experiments at three different size scales; the small Trondheim basins, the real scale COSS basins and the full field scale at Svalbard. It is important to recognize that each scale has a very different role and value with respect to our objectives, but that techniques will be consistent between trials.

The three stage, three phase approach is a building process, basically one of:

- (i) Trondheim: methods/technique development and the generation of data for field trials.
- (ii) COSS: testing of variables and extrapolation of data to different scenarios.
- (iii) Svalbard: field verification.

One of the primary functions of the Trondheim trials was for methods development, protocol verification, refinement of techniques and rangefinding. Methods development aspects included how to oil the sediments, define the study zone, collect samples, apply treatment, and analyze samples. The Trondheim trials were used to evaluate protocols, refine these techniques and be fully prepared before going to COSS and the field.

The COSS trials provided simulated real world environmental conditions with the ability to control and investigate variables. It is from the COSS basins that we will generate non-constrained hard data on the effects of varying wave energy.

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OFI is an event or process by which fine particles interact with oil in an aqueous environment and change the behavioural characteristics of the oil. OFI may create a stable water-sediment-oil emulsion and is thought to be an important component of the natural weathering of oil by enhancing and accelerating physical and biochemical degradation processes (Bragg and Yang, 1995).

The field trials will provide a full scale verification with all the environmental variables in play but without the ability to control the variables. The size of the plots allows use of cleanup techniques at a real scale (e.g., front end loaders).

## **BASIN TRIALS**

This first series of studies addresses two primary mechanisms for removal of oil in sediments, and in natural and enhanced natural scenarios. At one end of the spectrum is a process that occurs as a result of *mechanical abrasion* alone. Wave or surf action provides physical (hydraulic) energy for the movement of sediments and the subsequent mechanical abrasion of oil from the surface of those sediments. Such an abrasion process can occur in the absence of fine particles. The cleanup action in this case, to accelerate the process, is to push oiled sediments from above the intertidal zone (above the limit of wave action) or from the upper intertidal zone, to a lower part of the swash zone where energy levels are higher, or to till the oiled sediments to expose subsurface oil to a zone of active sediment movement. The other action is defined as OFI (oil and fines interaction) and can take place in the absence of mechanical wave energy. This involves *only interactions between oil and fine particles*, in the presence of water. In this process oil is removed by tidal water-level changes or other *in situ* flushing actions. The cleanup action in this instance is to push sediments around to make the oil more available and so accelerate this interaction.

The primary experimental variables are:

- wave energy (wave height)
- presence of fine particles (clays)
- sediment type
- temperature
- oil loading.

This first series of experiments has been designed to test with one oil type, IF30 - a number 4 fuel, and both the Trondheim and COSS basin tests employed complimentary experimental and measurement techniques.

### **Basin Trials - Objectives**

The general objectives of the Beach Basin Trials were to:

- ▶ verify and quantify those variables which control or influence the OFI process and the subsequent removal of oil from shoreline sediments,
- ▶ determine practical limits of natural and enhanced oil removal by OFI and mechanical abrasion processes, and
- ▶ provide guidance on the application of this process to both the experimental design of planned full-scale field trials and the operational decision-making for real-spill cleanup activities, i.e., how to predict and enhance natural processes to remove oil.

The specific objectives of both the individual Trondheim and COSS trials are described below.

## 1) Trondheim Beach Basin Trials Design

Among the primary functions of the Trondheim trials were methods development, protocol verification, refinement of techniques, and range finding. The objectives of these trials were to obtain measurements on removal of oil from beach sediments as a result of natural abrasion and accelerated abrasion.

Null Hypotheses to be tested were:

- 1. Wave energy and oil loading do not affect natural oil removal rates.*
- 2. Relocation of oiled sediments to zones of higher wave energy does not affect natural oil removal rates.*

The SINTEF Continuous Flow Basin System in Trondheim consists of four basins, simulating an open system with computer-controlled natural tidal variation and wave action, with a continuous supply and exchange of natural seawater. Each basin is 4 x 2 x 1 m; length, width and height, respectively. The basins are constructed of 10-mm PE plates, supported within an aluminium frame. Sea water is obtained from the Trondheim Fjord from a depth of approximately 80 m. The salinity of the sea water is approximately 35 ppt. The water temperature remains constant year round at approximately 12 °C.

### TEST MATRIX

<b>Oil</b>	IF30
<b>Sediments</b>	mixed coarse grained sediments from the Trondheim Fjord
<b>Wave Period</b>	1 and 3 seconds
<b>Wave Height</b>	0, 2 and 9 cm
<b>Oil Loading</b>	1 and 5 L/m <sup>2</sup>
<b>Oil Application</b>	directly onto sediments at low tide.

### TEST SETUP

Estimated cross-shore width of 0.5 m. Wait 12 hr before initiating tidal increase.

Total number of experiments (separate basin runs) = 12

Duration of each experiment = 36, 72, 204 hours

Number of complete tidal cycles = 3, 6 and 17 (i.e. number of flood tide exposures)

Table 1. Test matrix for the Trondheim basin trials - L designates oil loading and E designates wave energy (height and period).

Natural Removal	Accelerated Removal	Natural Removal	Accelerated Removal	Duration of experiments
L: 1 L/m <sup>2</sup> E: 2 cm, 3 s	L: 1 L/m <sup>2</sup> E: 2 cm, 3 s	L: 1 L/m <sup>2</sup> W: none	L: 1 L/m <sup>2</sup> W: none	36 hours
L: 5 L/m <sup>2</sup> W: 2 cm, 3 s	L: 5 L/m <sup>2</sup> E: 2 cm, 3 s	L: 5 L/m <sup>2</sup> W: none	L: 5 L/m <sup>2</sup> W: none	72 hours
L: 5 L/m <sup>2</sup> E: 9 cm, 1 s	L: 5 L/m <sup>2</sup> E: 9 cm, 1 s	L: 5 L/m <sup>2</sup> E: 2 cm, 3 s	L: 5 L/m <sup>2</sup> E: 2 cm, 3 s	204 hours

Two sets of experiments were carried out: one to study natural removal rates of oil, and the other to study accelerated removal of oil. The same test conditions were used for both sets of experiments. As indicated in the test matrix (Table 1), the oil loading was kept constant in each basin, while the wave energy was varied. The same sediment was reused in each basin. Only the oiled sediment was removed and replaced with clean sediment. The tidal cycle was run until the sediments had stabilised before reapplying oil for the next experiment.

Treatment took place after one complete tidal cycle (one complete flood of the oiled zone).

#### MEASUREMENTS AND SAMPLES

- one across shore composite sediment sample within the oiled zone at each of three low tides for TSEM analysis.
- one composite subtidal sediment sample at each of three low tides
- one water sample at high tide for oil particulate measurement
- recover oil and measure at high tide
- on rising tide pipette sample of flocs at w/s interface
- conduct test for OFI
- beach slope every low tide
- grain size analysis
- temperature, salinity

## 2) COSS Beach Basin Trials Design

The objective of these trials was to obtain measurements on removal of oil from beach sediments (a) in the presence and absence of clays, and (b) as a result of natural abrasion and accelerated abrasion.

The Null Hypotheses to be tested were:

1. *The presence of clays does not affect natural oil removal rates in the absence of wave energy.*
2. *Wave energy and oil loading do not affect the rate of physical removal of oil.*
3. *The mixing of oiled sediments does not affect the rate of physical removal of oil.*

The nine COSS tanks are 30.48 m in length, 2.13 m wide and 2.44 m deep and have a flow-through system that connects directly to waters of the Gulf of Mexico (Kitchen *et al.*, 1997). The system has wave makers and can simulate diurnal and semi-diurnal tides.

The sediment used throughout was a well-sorted pebble mixed with sands. The sands were predominantly in the 0.3 to 0.6 mm size range, with a coarse tail. The pebble-granule-sand content was approximately 45%, 12 % and 42% and the resulting mixture intentionally similar to the sediments found in the Svea region, where the summer field experiments are to be held. A well-sorted beach was generated by strong wave action and this produced an upper surface layer of 1 to 2 cm of well-sorted sand over a mixed sediment substrate and a lower section with a surface layer of 2 to 3 well-sorted pebbles over a mixed sediment substrate.

In the first set of tests the constants were oil loading ( $0.5 \text{ L/m}^2$ ) and wave action (none). Water motion was imparted by a 1 inch and 10 second wave that was observed not to move sediments in the swash zone. Two sediment types were used in separate tanks: a washed sand-pebble, and an unwashed sand-pebble mixture with clays (kaolinite) added to the near-beach water (Table 2).

First Test Matrix	
<b>Sediments</b>	sand and pebbles (washed); unwashed sand, pebbles; clay
<b>Wave Height</b>	1 inch (2.5 cm)
<b>Wave Period</b>	10 seconds
<b>Oil</b>	IF30
<b>Oil Loading</b>	$0.5 \text{ l/m}^2$

Table 2. COSS Basin Trials - first test set - no wave action.

washed sand-pebble	unwashed sand-pebble with added clay	washed sand-pebble: raked	unwashed sand-pebble with added clay: raked
# 1 surface pebbles	# 2 surface pebbles	# 3 surface pebbles	# 4 surface pebbles
# 5 surface sands	# 6 surface sands	# 7 surface sands	# 8 surface sands

The second set of tests involved a series based on a combination of increasing oil loadings and wave heights to provide data on removal rates by physical abrasion.

Second Test Matrix	
<b>Sediments</b>	sand and pebbles (washed); unwashed sand, pebbles clay
<b>Wave Height</b>	1 - 12 inches (2.5 to 30 cm)
<b>Wave Period</b>	5 - 10 seconds
<b>Oil</b>	IF30
<b>Oil Loading</b>	low and high
<b>Treatment</b>	mixing (simulated tilling)

## SVALBARD FIELD TRIALS

The objectives and null hypothesis for the field trials will be based on the Trondheim and COSS Basin tests. At the time of writing, the results from the COSS trials were not fully analyzed so some modification may be anticipated with respect to the specific objectives and field protocols.

The basic primary objective of the field experiments is to quantify the effectiveness of selected *in situ* shoreline treatment options.

The goals are to deliver both operational and scientific information which will assist decision makers in selecting the most appropriate technique to suit the conditions, and also to increase knowledge of the natural removal processes for stranded oil.

It should be noted that, although the field trials themselves are being conducted in a high latitude location, the results have a widespread application to other coarse sediment beaches in any latitude. The extrapolation is expanded even further when supplemented with the basin trials data.

### **Test Location and Sites**

The field experiments will be conducted near the mining town of Sveagruva on Spitsbergen, the largest island in Svalbard (Figure 1). Sveagruva is located on the Van Mijenfjord, approximately 40 km from the open ocean and at approximately 76°56' North and 16°45' East.

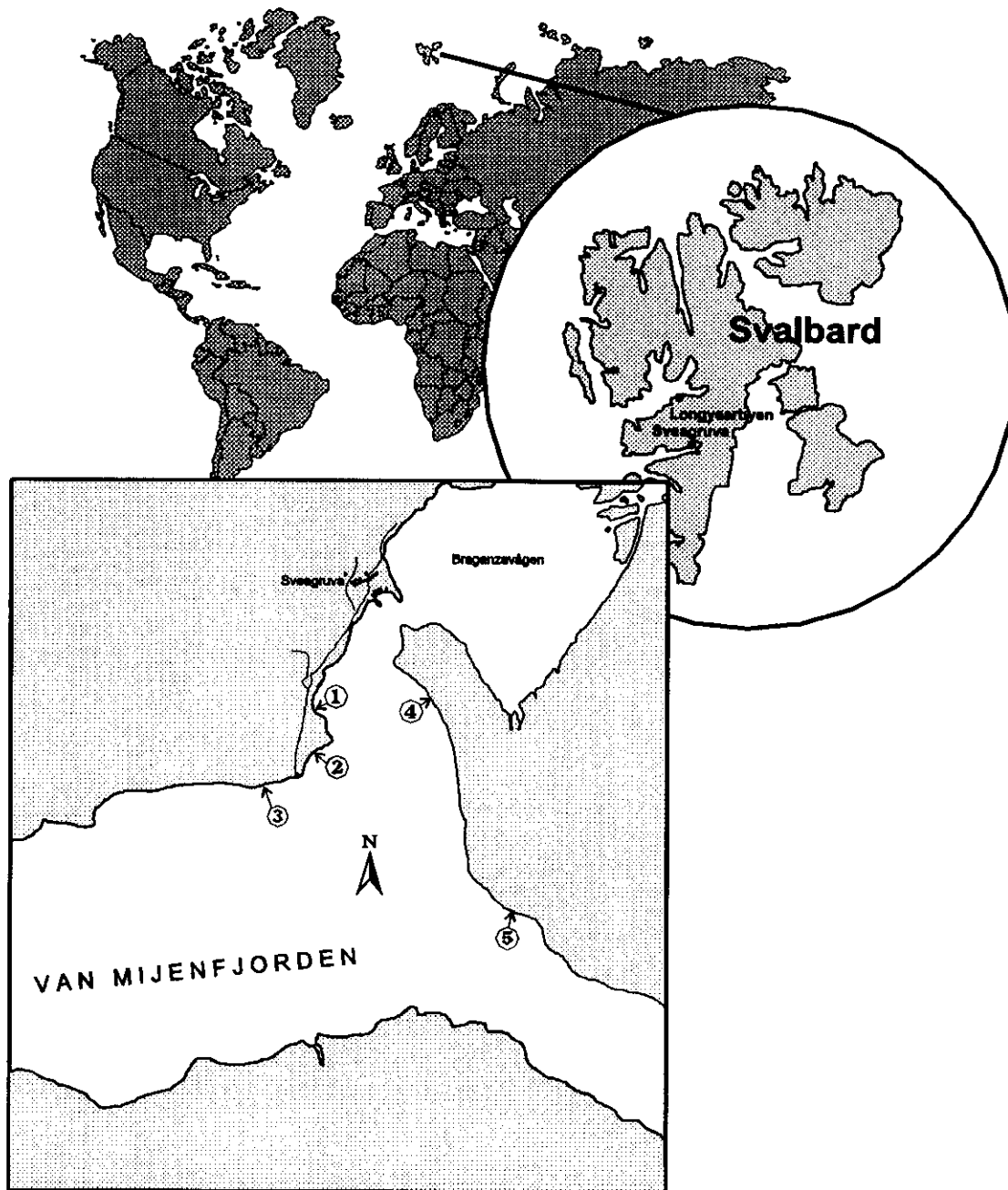
Within this fjord, a total of five beaches were surveyed and assessed in August 1996, as potential sites for the 1997 experiments. These beaches (numbered 1 to 5) are indicated on Figure 1. All beaches are located approximately within 5-6 km of Sveagruva, except for Beach #5 which is approximately 10 km away.

At Sveagruva, ambient air temperatures in summer (June to September) average 0° to 6°C. Water temperatures range from -1° to 4°C in the summer. The salinity in the fjord is approximately 35 ppt and precipitation averages between 11 and 20 mm during this period. The ice typically leaves the fjord sometime between early to mid-July, with the shorelines becoming ice-free by late July. During the summer of 1996, the shorelines were already ice-free by mid-July. The coastal processes remain active until the beaches begin to freeze over in late November or early December. Winds during the open-water season are generally light as the region is dominated by the Polar High. Summer winds are generally light during the period June through September. The period of strongest winds occurs from November through March, coincidental with the presence of sea ice that prevents wave generation and shorefast ice that encases the beaches. Strong katabatic winds can occur near the glaciers, particularly in late autumn and early winter. The tides are mixed semi-diurnal (two high and two low each day of unequal height) and the tidal range varies between 1.2 m and 1.8 m, depending on the spring or neap phases.

### **Experimental Strategy**

The experimental strategy for the field trials is linked to the different project phases and basically includes:

1. Planning, organization, and experimental design.
2. Background studies, site characterization and initial control plot - summer 1996.
3. Meso-scale beach basin trials - Trondheim and COSS spring 1997.
4. Field trials - summer of 1997.



5. Long term post-trial monitoring of field trial sites - 1998.

6. Optional follow-on studies - 1998.

Figure 1. Location of Svalbard and Candidate Beaches

### 1996 Svalbard Field Trials

The 1996 field season of the Svalbard Shoreline Field Trials was conducted between July 20 and August 20th. Baseline field work and field protocol development were successfully completed and the results will be used in the design of the full-scale field trials scheduled for 1997. The 1996 field activities and objectives were as follows.

- Beach surveys were conducted to document shoreline and substrate character and to determine those segments suitable for the experimental field trials.
- Oil penetration and short term retention testing were conducted using the test oil IF 30, a residual #4 fuel oil.
- Options for oil release were examined and a test discharge system constructed.
- A single plot was oiled and monitored for two weeks to document changes in oil cover, penetration, and loading and test experimental design.
- Protocols were tested for the collection of samples and extraction of oil from bulk sediment samples.

Suitable sites for the 1997 field trials were located on Beaches 1, 2 and 4. Beach #2 would be used for a tilling, bioremediation, tilling combined with bioremediation, and a control plot. This beach has the longest stretch of suitable intertidal sediment and will therefore permit all plots to be located on similar sediments with similar exposure. Beach #1 is recommended for surf washing (sediment relocation) in a low energy setting. Surf washing likely also will be carried out on Beach #4, a relatively high energy shore within the fjord. Previous cleanup operations have demonstrated that surf washing can be an effective technique, but quantitative data has not been collected during these spill events. A surf washing study on Beach #4 would provide relevant data to support this technique.

It was concluded that the IF 30 oil can be used in the 1997 field trials without modification. This same oil was used in the beach basin experiments in Trondheim and Texas. An estimated oil loading of  $5\text{L/m}^2$  will be used, however the final loading will be based on analysis of the results from the basin experiments.

### **Experimental Design of the 1997 Svalbard Field Trials**

Basic elements of the 1997 Svalbard Shoreline Field Trials are likely to include:

- the use of five treatment options (surf washing, tilling, bioremediation, tilling plus bioremediation, natural recovery),
- one oil type (IF 30), and
- realistic sized plots, each 30-40 m in alongshore length.

The oil will be applied in a controlled and uniform manner in the upper intertidal zone. It will be applied directly to the sediment surface (not the water) which will maximize control over both the oil and the uniformity of oiling to the intertidal area. The oil will be applied on a low or falling tide, to simulate 'natural' stranding. The current estimated

loading will be in the range of 5 L/m<sup>2</sup>. Treatments will be applied after the oil on the beach has been stabilized by tidal washing.

A range of measurements, observations and sample collections will be carried out within and outside each of the plots, before and following the application of oil and/or treatment. These activities will include:

- observations on the physical character of the shoreline
- measurement of oil distribution
- sample collection and determination of the quantity of oil within each oiled plot
- determination of the quantity of oil outside the plots: (lower intertidal sediments; nearshore sediments and water; between plot buffer zone)
- observations and sample collection of fine particle interaction
- biodegradation-related analysis (oil composition, microbial analysis)

The top of each plot will be located at or just below the spring high water mark and will include all of the UITZ. Depending on the treatment, plot sizes of 30 - 40 m alongshore length and 3 - 4 m cross shore width will be used. Timing for oiling and treating the plots will be coordinated with specific phases of the monthly cycle of spring and neap tides. The strategy will be to allow the maximum time for the oil to penetrate and adhere into the sediment before natural tidal flushing and application of treatment techniques. All test plots will be oiled during the neap tide phase from July 28 to July 31, 1997. The treatments will be carried out during the peak of the spring tide phase, approximately 8 to 10 days after oiling. An additional option is also proposed for treatment after 72 hours.

A systematic sample scheme will be used on the plots (as per 1996) taking one sample per bloc per sample period. A sample size of about 2 kg - 3kg or about 1.5 L will be used. This is of sufficient size to overcome sediment heterogeneity. In most cases, intertidal surface and subsurface will not be separated or sub-sampled. A single sample will be composed of a vertical composite of sediment from the surface to a fixed depth. Based on analysis of 1996 data, an estimated 10 samples per 4 x 20 m plot is deemed adequate. In the case of surf washing where the sediments on the oiled plot have been moved, then the sampling grid for the relocated sediment berms will be contoured to the shape and redistribution of the berms.

The basic bulk sediment extraction protocol used in 1996 will be used in 1997 with modifications in equipment to improve efficiency. These have been verified in the beach basin trials in Texas and Trondheim. Total oil will be determined by gravimetric total solvent extractable material (TSEM). Samples will be archived for potential future GC-TPH or GCMS.

## **DISCUSSION**

This three-tiered set of studies in the ITOSS Programme is part of a larger framework of linked studies being carried out by various agencies in a long-term strategy to better understand the fate and behaviour of oil on shorelines. As results and recommendations are generated, they will be used to develop appropriate response guidelines for oiled shorelines, particularly in remote areas. This discussion provides an outline of the objectives and design parameters of the three basin and field studies that are presently in

progress.

## ACKNOWLEDGEMENTS

The *In-situ* Treatment of Oiled Sediment Shorelines Programme is being financially sponsored by the following agencies: Canadian Coast Guard, Department of Fisheries and Oceans (Canada), Environment Canada, Exxon Research, Imperial Oil Canada, Marine Pollution Control Unit (UK), Minerals Management Service (USA), Norwegian Pollution Control Authority, Swedish Rescue Agency, and the Texas General Land Office.

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- wave energy (wave height)
- presence of fine particles (clays)
- sediment type
- temperature
- oil loading.

This first series of experiments has been designed to test with one oil type, IF30 - a number 4 fuel, and both the Trondheim and COSS basin tests employed complimentary experimental and measurement techniques.

### **Basin Trials - Objectives**

The general objectives of the Beach Basin Trials were to:

- ▶ verify and quantify those variables which control or influence the OFI process and the subsequent removal of oil from shoreline sediments,
- ▶ determine practical limits of natural and enhanced oil removal by OFI and mechanical abrasion processes, and
- ▶ provide guidance on the application of this process to both the experimental design of planned full-scale field trials and the operational decision-making for real-spill cleanup activities, i.e., how to predict and enhance natural processes to remove oil.

The specific objectives of both the individual Trondheim and COSS trials are described below.

## 1) Trondheim Beach Basin Trials Design

Among the primary functions of the Trondheim trials were methods development, protocol verification, refinement of techniques, and range finding. The objectives of these trials were to obtain measurements on removal of oil from beach sediments as a result of natural abrasion and accelerated abrasion.

Null Hypotheses to be tested were:

- 1. Wave energy and oil loading do not affect natural oil removal rates.*
- 2. Relocation of oiled sediments to zones of higher wave energy does not affect natural oil removal rates.*

The SINTEF Continuous Flow Basin System in Trondheim consists of four basins, simulating an open system with computer-controlled natural tidal variation and wave action, with a continuous supply and exchange of natural seawater. Each basin is 4 x 2 x 1 m; length, width and height, respectively. The basins are constructed of 10-mm PE plates, supported within an aluminium frame. Sea water is obtained from the Trondheim Fjord from a depth of approximately 80 m. The salinity of the sea water is approximately 35 ppt. The water temperature remains constant year round at approximately 12 °C.

### TEST MATRIX

<b>Oil</b>	IF30
<b>Sediments</b>	mixed coarse grained sediments from the Trondheim Fjord
<b>Wave Period</b>	1 and 3 seconds
<b>Wave Height</b>	0, 2 and 9 cm
<b>Oil Loading</b>	1 and 5 L/m <sup>2</sup>
<b>Oil Application</b>	directly onto sediments at low tide.

### TEST SETUP

Estimated cross-shore width of 0.5 m. Wait 12 hr before initiating tidal increase.

Total number of experiments (separate basin runs) = 12

Duration of each experiment = 36, 72, 204 hours

Number of complete tidal cycles = 3, 6 and 17 (i.e. number of flood tide exposures)

Table 1. Test matrix for the Trondheim basin trials - L designates oil loading and E designates wave energy (height and period).

Natural Removal	Accelerated Removal	Natural Removal	Accelerated Removal	Duration of experiments
L: 1 L/m <sup>2</sup> E: 2 cm, 3 s	L: 1 L/m <sup>2</sup> E: 2 cm, 3 s	L: 1 L/m <sup>2</sup> W: none	L: 1 L/m <sup>2</sup> W: none	36 hours
L: 5 L/m <sup>2</sup> W: 2 cm, 3 s	L: 5 L/m <sup>2</sup> E: 2 cm, 3 s	L: 5 L/m <sup>2</sup> W: none	L: 5 L/m <sup>2</sup> W: none	72 hours
L: 5 L/m <sup>2</sup> E: 9 cm, 1 s	L: 5 L/m <sup>2</sup> E: 9 cm, 1 s	L: 5 L/m <sup>2</sup> E: 2 cm, 3 s	L: 5 L/m <sup>2</sup> E: 2 cm, 3 s	204 hours

Two sets of experiments were carried out: one to study natural removal rates of oil, and the other to study accelerated removal of oil. The same test conditions were used for both sets of experiments. As indicated in the test matrix (Table 1), the oil loading was kept constant in each basin, while the wave energy was varied. The same sediment was reused in each basin. Only the oiled sediment was removed and replaced with clean sediment. The tidal cycle was run until the sediments had stabilised before reapplying oil for the next experiment.

Treatment took place after one complete tidal cycle (one complete flood of the oiled zone).

#### MEASUREMENTS AND SAMPLES

- one across shore composite sediment sample within the oiled zone at each of three low tides for TSEM analysis.
- one composite subtidal sediment sample at each of three low tides
- one water sample at high tide for oil particulate measurement
- recover oil and measure at high tide
- on rising tide pipette sample of flocs at w/s interface
- conduct test for OFI
- beach slope every low tide
- grain size analysis
- temperature, salinity

## 2) COSS Beach Basin Trials Design

The objective of these trials was to obtain measurements on removal of oil from beach sediments (a) in the presence and absence of clays, and (b) as a result of natural abrasion and accelerated abrasion.

The Null Hypotheses to be tested were:

1. *The presence of clays does not affect natural oil removal rates in the absence of wave energy.*
2. *Wave energy and oil loading do not affect the rate of physical removal of oil.*
3. *The mixing of oiled sediments does not affect the rate of physical removal of oil.*

The nine COSS tanks are 30.48 m in length, 2.13 m wide and 2.44 m deep and have a flow-through system that connects directly to waters of the Gulf of Mexico (Kitchen *et al.*, 1997). The system has wave makers and can simulate diurnal and semi-diurnal tides.

The sediment used throughout was a well-sorted pebble mixed with sands. The sands were predominantly in the 0.3 to 0.6 mm size range, with a coarse tail. The pebble-granule-sand content was approximately 45%, 12 % and 42% and the resulting mixture intentionally similar to the sediments found in the Svea region, where the summer field experiments are to be held. A well-sorted beach was generated by strong wave action and this produced an upper surface layer of 1 to 2 cm of well-sorted sand over a mixed sediment substrate and a lower section with a surface layer of 2 to 3 well-sorted pebbles over a mixed sediment substrate.

In the first set of tests the constants were oil loading ( $0.5 \text{ L/m}^2$ ) and wave action (none). Water motion was imparted by a 1 inch and 10 second wave that was observed not to move sediments in the swash zone. Two sediment types were used in separate tanks: a washed sand-pebble, and an unwashed sand-pebble mixture with clays (kaolinite) added to the near-beach water (Table 2).

First Test Matrix	
<b>Sediments</b>	sand and pebbles (washed); unwashed sand, pebbles; clay
<b>Wave Height</b>	1 inch (2.5 cm)
<b>Wave Period</b>	10 seconds
<b>Oil</b>	IF30
<b>Oil Loading</b>	$0.5 \text{ l/m}^2$

Table 2. COSS Basin Trials - first test set - no wave action.

washed sand- pebble	unwashed sand-pebble with added clay	washed sand- pebble: raked	unwashed sand-pebble with added clay: raked
# 1 surface pebbles	# 2 surface pebbles	# 3 surface pebbles	# 4 surface pebbles
# 5 surface sands	# 6 surface sands	# 7 surface sands	# 8 surface sands

The second set of tests involved a series based on a combination of increasing oil loadings and wave heights to provide data on removal rates by physical abrasion.

Second Test Matrix	
<b>Sediments</b>	sand and pebbles (washed); unwashed sand, pebbles clay
<b>Wave Height</b>	1 - 12 inches (2.5 to 30 cm)
<b>Wave Period</b>	5 - 10 seconds
<b>Oil</b>	IF30
<b>Oil Loading</b>	low and high
<b>Treatment</b>	mixing (simulated tilling)

## SVALBARD FIELD TRIALS

The objectives and null hypothesis for the field trials will be based on the Trondheim and COSS Basin tests. At the time of writing, the results from the COSS trials were not fully analyzed so some modification may be anticipated with respect to the specific objectives and field protocols.

The basic primary objective of the field experiments is to quantify the effectiveness of selected *in situ* shoreline treatment options.

The goals are to deliver both operational and scientific information which will assist decision makers in selecting the most appropriate technique to suit the conditions, and also to increase knowledge of the natural removal processes for stranded oil.

It should be noted that, although the field trials themselves are being conducted in a high latitude location, the results have a widespread application to other coarse sediment beaches in any latitude. The extrapolation is expanded even further when supplemented with the basin trials data.

### **Test Location and Sites**

The field experiments will be conducted near the mining town of Sveagruva on Spitsbergen, the largest island in Svalbard (Figure 1). Sveagruva is located on the Van Mijenfjord, approximately 40 km from the open ocean and at approximately 76°56' North and 16°45' East.

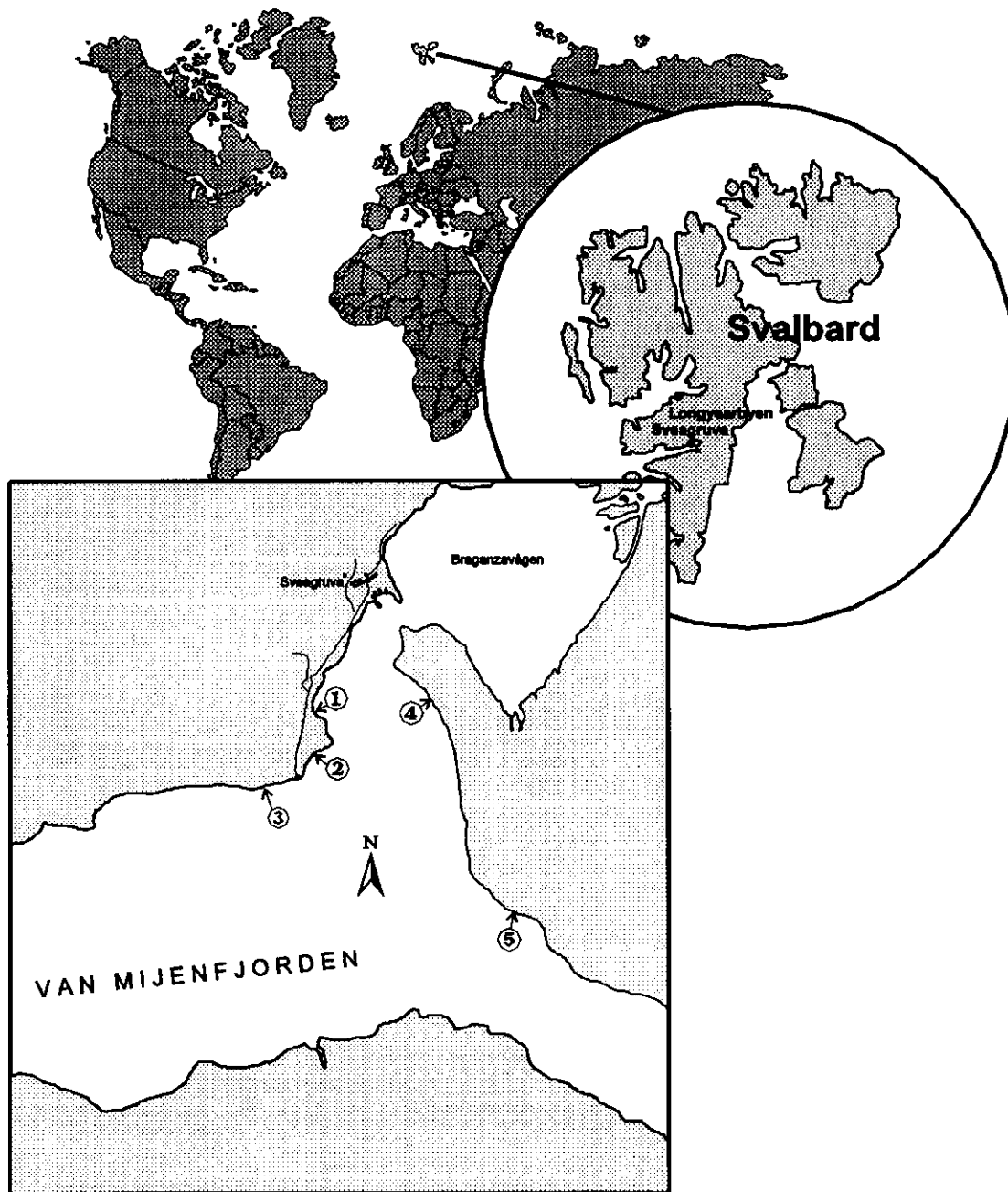
Within this fjord, a total of five beaches were surveyed and assessed in August 1996, as potential sites for the 1997 experiments. These beaches (numbered 1 to 5) are indicated on Figure 1. All beaches are located approximately within 5-6 km of Sveagruva, except for Beach #5 which is approximately 10 km away.

At Sveagruva, ambient air temperatures in summer (June to September) average 0° to 6°C. Water temperatures range from -1° to 4°C in the summer. The salinity in the fjord is approximately 35 ppt and precipitation averages between 11 and 20 mm during this period. The ice typically leaves the fjord sometime between early to mid-July, with the shorelines becoming ice-free by late July. During the summer of 1996, the shorelines were already ice-free by mid-July. The coastal processes remain active until the beaches begin to freeze over in late November or early December. Winds during the open-water season are generally light as the region is dominated by the Polar High. Summer winds are generally light during the period June through September. The period of strongest winds occurs from November through March, coincidental with the presence of sea ice that prevents wave generation and shorefast ice that encases the beaches. Strong katabatic winds can occur near the glaciers, particularly in late autumn and early winter. The tides are mixed semi-diurnal (two high and two low each day of unequal height) and the tidal range varies between 1.2 m and 1.8 m, depending on the spring or neap phases.

### **Experimental Strategy**

The experimental strategy for the field trials is linked to the different project phases and basically includes:

1. Planning, organization, and experimental design.
2. Background studies, site characterization and initial control plot - summer 1996.
3. Meso-scale beach basin trials - Trondheim and COSS spring 1997.
4. Field trials - summer of 1997.



5. Long term post-trial monitoring of field trial sites - 1998.

6. Optional follow-on studies - 1998.

Figure 1. Location of Svalbard and Candidate Beaches

### 1996 Svalbard Field Trials

The 1996 field season of the Svalbard Shoreline Field Trials was conducted between July 20 and August 20th. Baseline field work and field protocol development were successfully completed and the results will be used in the design of the full-scale field trials scheduled for 1997. The 1996 field activities and objectives were as follows.

- Beach surveys were conducted to document shoreline and substrate character and to determine those segments suitable for the experimental field trials.
- Oil penetration and short term retention testing were conducted using the test oil IF 30, a residual #4 fuel oil.
- Options for oil release were examined and a test discharge system constructed.
- A single plot was oiled and monitored for two weeks to document changes in oil cover, penetration, and loading and test experimental design.
- Protocols were tested for the collection of samples and extraction of oil from bulk sediment samples.

Suitable sites for the 1997 field trials were located on Beaches 1, 2 and 4. Beach #2 would be used for a tilling, bioremediation, tilling combined with bioremediation, and a control plot. This beach has the longest stretch of suitable intertidal sediment and will therefore permit all plots to be located on similar sediments with similar exposure. Beach #1 is recommended for surf washing (sediment relocation) in a low energy setting. Surf washing likely also will be carried out on Beach #4, a relatively high energy shore within the fjord. Previous cleanup operations have demonstrated that surf washing can be an effective technique, but quantitative data has not been collected during these spill events. A surf washing study on Beach #4 would provide relevant data to support this technique.

It was concluded that the IF 30 oil can be used in the 1997 field trials without modification. This same oil was used in the beach basin experiments in Trondheim and Texas. An estimated oil loading of 5L/m<sup>2</sup> will be used, however the final loading will be based on analysis of the results from the basin experiments.

### **Experimental Design of the 1997 Svalbard Field Trials**

Basic elements of the 1997 Svalbard Shoreline Field Trials are likely to include:

- the use of five treatment options  
(surf washing, tilling, bioremediation, tilling plus bioremediation, natural recovery),
- one oil type (IF 30), and
- realistic sized plots, each 30-40 m in alongshore length.

The oil will be applied in a controlled and uniform manner in the upper intertidal zone. It will be applied directly to the sediment surface (not the water) which will maximize control over both the oil and the uniformity of oiling to the intertidal area. The oil will be applied on a low or falling tide, to simulate 'natural' stranding. The current estimated

loading will be in the range of 5 L/m<sup>2</sup>. Treatments will be applied after the oil on the beach has been stabilized by tidal washing.

A range of measurements, observations and sample collections will be carried out within and outside each of the plots, before and following the application of oil and/or treatment. These activities will include:

- observations on the physical character of the shoreline
- measurement of oil distribution
- sample collection and determination of the quantity of oil within each oiled plot
- determination of the quantity of oil outside the plots: (lower intertidal sediments; nearshore sediments and water; between plot buffer zone)
- observations and sample collection of fine particle interaction
- biodegradation-related analysis (oil composition, microbial analysis)

The top of each plot will be located at or just below the spring high water mark and will include all of the UITZ. Depending on the treatment, plot sizes of 30 - 40 m alongshore length and 3 - 4 m cross shore width will be used. Timing for oiling and treating the plots will be coordinated with specific phases of the monthly cycle of spring and neap tides. The strategy will be to allow the maximum time for the oil to penetrate and adhere into the sediment before natural tidal flushing and application of treatment techniques. All test plots will be oiled during the neap tide phase from July 28 to July 31, 1997. The treatments will be carried out during the peak of the spring tide phase, approximately 8 to 10 days after oiling. An additional option is also proposed for treatment after 72 hours.

A systematic sample scheme will be used on the plots (as per 1996) taking one sample per bloc per sample period. A sample size of about 2 kg - 3kg or about 1.5 L will be used. This is of sufficient size to overcome sediment heterogeneity. In most cases, intertidal surface and subsurface will not be separated or sub-sampled. A single sample will be composed of a vertical composite of sediment from the surface to a fixed depth. Based on analysis of 1996 data, an estimated 10 samples per 4 x 20 m plot is deemed adequate. In the case of surf washing where the sediments on the oiled plot have been moved, then the sampling grid for the relocated sediment berms will be contoured to the shape and redistribution of the berms.

The basic bulk sediment extraction protocol used in 1996 will be used in 1997 with modifications in equipment to improve efficiency. These have been verified in the beach basin trials in Texas and Trondheim. Total oil will be determined by gravimetric total solvent extractable material (TSEM). Samples will be archived for potential future GC-TPH or GCMS.

## **DISCUSSION**

This three-tiered set of studies in the ITOSS Programme is part of a larger framework of linked studies being carried out by various agencies in a long-term strategy to better understand the fate and behaviour of oil on shorelines. As results and recommendations are generated, they will be used to develop appropriate response guidelines for oiled shorelines, particularly in remote areas. This discussion provides an outline of the objectives and design parameters of the three basin and field studies that are presently in

progress.

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